QIE8 Non-inverting mode test results

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I have looked at the QIE8 production chip behavior in non-inverting mode in more detail, and would like to document some results.

Input Impedance

The non-inverting input impedance in both 50 and 93 ohm modes depends significantly on the magnitude of (Vin – Vclamp). Vclamp is set internally and only needs to be bypassed externally. Tests of many chips show that the value of (Vin – Vclamp) has an approximately Gaussian distribution, and that this value for most of the chips falls within +/- 3 mV of the mean value (+/- 3 sigma approximately). Tests show that for every 2 mV increase in (Vin – Vclamp), the input impedance increases by about 3%. Thus unsorted parts will probably have about a +/- 5% spread in the input impedance. If desired, cuts can be placed on the parts when testing to tighten up this spread. Parts which don't meet the cut but are otherwise completely functional would still be completely useable for HCAL, since the inverting input amp is completely separate and does not use Vclamp.

The non-inverting input impedance is also dependent on the value of R_{NI_ISET}. A 1 Kohm increase in the value of this external resistor results in about a 3% increase in the input impedance. Thus, this value may be used to adjust the impedance around the nominal for a given cable. Once the cable to be used is selected, then the value of R_{NI_ISET} should be optimized. In 50 ohm mode, a 50 ohm input impedance is achieved with a value of approximately 11 Kohms. In 93 ohm mode, a 93 ohm input impedance is achieved with a value of approximately 12 Kohms. A 98 ohm input impedance is achieved with a value of about 14 Kohms.

As has been advertised before, the input impedance tends to go up for pulses of large magnitude. The input impedance is found by measuring the input voltage swing at the QIE input and dividing it by the peak input current of a square pulse.

For 50 ohm mode:

Peak Input Current	Input R
0.25 mA	50
0.5 mA	50
1.0 mA	50.8
1.5 mA	52.2
2.0 mA	53.6
2.5 mA	55.0

For 93 ohm mode (R_{NI_ISET} = 14 K):

Peak Input Current	Input R
0.125 mA	98
0.25 mA	98
0.5 mA	100
1.0 mA	104
1.5 mA	109
2.0 mA	112
2.5 mA	115

If it is necessary to obtain a more constant "93 ohm" input impedance with input magnitude, the QIE can be set to 50 ohm mode and a series cable termination resistor added (I used 47 ohms). HOWEVER, it should be noted that this method carries an associated penalty of an increase in the noise. See below for noise measurements.

For 50 ohm mode with added 47 ohm resistor:

Peak Input Current	Input R
0.25 mA	96.0
0.5 mA	96.0
1.0 mA	96.4
1.5 mA	97.7
2.0 mA	98.9
2.5 mA	100.2

Pulse Response

The time response of the QIE8 to small amplitude pulses is determined to some extent by the input bias current, which is set by R_{NI_INBIAS}. It is desirable to integrate all of a fast PMT pulse (< 10 ns wide) within one clock period (25 ns). The recommendation for this resistor value is 220K. However, it may be acceptable to increase this resistance (decrease the input bias current) while still maintaining adequate response.

If an 8 ns wide (base to base) small amplitude triangular pulse is applied directly to the QIE8 input, virtually all the charge is integrated in 10 ns with R_{NI_INBIAS} = 220K. If R_{NI_INBIAS} is increased to 440K, this time increases to 15 ns, still well within one 25 ns clock period. Increasing R_{NI_INBIAS} has the advantage of offering some reduction in the noise.

In addition to the "smearing out" of the pulse by the QIE8, the input cable also smears the pulse depending on cable type, length, attenuation, etc. I gave some results for this effect in the “QIE Input Cable Studies” document of 3/05/02, but some of these (at least for 93 ohm cables) appear to be in error.

Applying a 8 ns wide triangular pulse to a 3m long RG180 cable (93 ohms): about 95% of the charge arrives in 8 ns, the remaining 5% is smeared out over the next 6 ns or so.

Applying the same pulse to a 4.6m long minicoax cable (93 ohms): about 90% of the total charge arrives in 8 ns, the remaining 10% is smeared out over the next 35 ns or so.

Obviously the cable choice can have a big effect on the charge profile arriving at the QIE input. The choice of R_{NI_INBIAS} will further influence the internal charge profile arriving at the QIE integrators (for small amplitude pulses). Choosing R_{NI_INBIAS} = 150K results in almost no additional smearing of the pulse, whereas R_{NI_INBIAS} = 440K can potentially widen the pulse by 5 – 10 ns.

Noise

Unfortunately, the input referred noise for the non-inverting input measured on the QIE8 production chip yields higher numbers than corresponding measurements made on the prototype chip. However, a similar comparison for inverting amplifier noise shows no such increase. This is not understood, however, it should be noted that a significant portion of the non-inverting amplifier noise comes from an NMOS FET, whereas the inverting amplifier noise sources are mostly BJTs. There could well be run to run variations in FET noise.

Cable type	Cable length	R_{NI_ISEL}	Noise
50 ohm RG58	3.1m	220K	14,500e
50 ohm RG58	3.1m	440K	12,800e
50 ohm RG58	4.6m	220K	15,300e
50 ohm RG58	4.6m	440K	13,800e
93 ohm RG180	3.0m	220K	8400e
93 ohm RG180	3.0m	440K	7500e
93 ohm minicoax	4.6m	220K	9000e
93 ohm minicoax	4.6m	440K	8000e

If the 3m RG180 cable (93 ohm) is terminated by the QIE in 50 ohm mode with an external series 43 ohm resistor (to keep a more constant input impedance), the noise is 8900e (for R_{NI_INBIAS} = 440K). The 43 ohm resistor and the cable add 4800e to the existing QIE noise.